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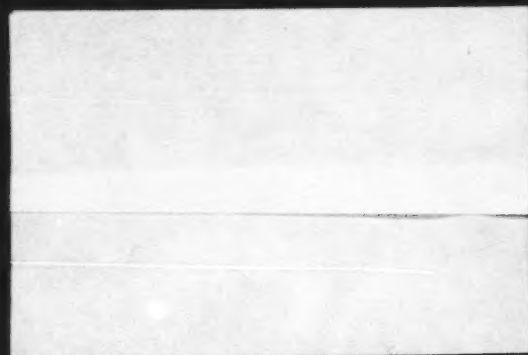
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ABSTRACT

This document reviews current literature, and contains the following section titles: General background; Current position in New Zealand and trends; Cross-cultural studies; Spatial visualization and problem solving; Achievement; Attitudes; Attitudes and Achievement; Mathematics as useful; Confidence in mathematics ability; Socialization/sex typing; Women in mathematics-related fields; Home environment; School environment; Type of school; Careers; and Summary. It is noted that the studies vary in their reports of exactly when sex differences in mathematics achievement emerge, but generally it is reported that there are few differences at the primary level. It is in high school that males pull ahead. Even when participation and achievement are almost equal in middle high school, as is the case for recent New Zealand school certificate exams, girls are still less likely than boys to continue with mathematics. It is felt that useful investigations could look further into the relationship between the development of attitudes towards mathematics and participation and achievement in mathematics. (MP)

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SEX DIFFERENCES
IN MATHEMATICS

CLAIRE STEWART

February 1981

SEX DIFFERENCES IN MATHEMATICS

1 General Background

Sex differences in mathematics have been the subject of much research in recent years. At primary level there appears to be no significant sex differences in the performance of mathematics, yet at higher secondary levels and beyond fewer women are to be found taking mathematics. (Skypek 1980, Keeves 1972, Hilton and Berglund 1976). What factors give rise to this situation is a matter of debate. The consequences are clear. Many possible job options are cut off for those people who have not continued to take mathematics to a high enough level. Williams (1980) states "it is the more numerate who keep their jobs and end up in 'better' jobs". This is especially the case with technological developments in many fields and the skills required for jobs in those areas. It appears that an early awareness is crucial. A decision not to continue with mathematics has long term effects. A study by Wise (1979) found that virtually no one who had not planned a mathematics related career by twelfth grade had switched to a mathematics related career by the age of twenty-nine.

2 Current Position in New Zealand and Trends

In the period from 1970 to 1979 the total numbers of students taking mathematics in forms 3 and 4 has remained the same (almost 100%), though the distribution between core and full mathematics has changed. Mathematics as a school certificate subject is now the second most popular choice for candidates. The greatest increase in numbers taking mathematics has been for girls at the form 5 and 6 levels (for example, from 46% of fifth form girls in 1970 to 79% in 1979). Often students have more options in the courses that they take once they reach the fifth form. Despite the increases that have occurred girls are still not as likely as boys to opt for mathematics in the sixth and seventh forms.

Table 1: Percentage of students taking mathematics.*

Full Mathematics

	1970		1979	
	<u>Male</u>	<u>Female</u>	<u>Male</u>	<u>Female</u>
Form 3	85	70	74	73
4	86	63	74	73
5 (1st year)	82	46	86	79
5 (other)	68	20	78	54
6	77	41	85	64
7	81	52	77	56

Core Mathematics

	1970		1979	
	Male	Female	Male	Female
Form 3	15	30	25	26
4	13	34	23	25
5 (1st year)	5	6	5	5
5 (other)	4	4	4	5

The trend that emerges in the later high school years for girls not to take mathematics in equal numbers to boys continues into tertiary educational levels. At each level women form a smaller proportion of the total.

Table 2a: First Degree Courses Taken by Internal Students 1979.*

	Male	Female
Science	3,586	1,547
Engineering	1,472	43
Arts	3,679	6,735

Table 2b: Degrees obtained in Mathematics and English in 1970 and 1979.*

Degree	1970				1979			
	Mathematics		English		Mathematics		English	
	Male	Female	Male	Female	Male	Female	Male	Female
Bachelors	191	30	174	319	126	47	119	302
Bachelors (Honours)	26	5	2	3	32	10	7	23
Masters	16	1	7	7	9	-	2	3
Masters (Honours)	26	2	39	60	9	2	20	37
PHD	-	-	2	2	4	-	1	2

A review of 1979 school certificate mathematics grades shows that a similar percentage of boys and girls passed school certificate mathematics. For both sexes the pass rate was around fifty-four percent. The spread of grades was very even, though there were slightly more boys who received grade A. In the 1970 School Certificate mathematics exam, girls achieved a higher pass rate than did boys. This may have been because the smaller proportion of girls sitting the exam represented a select group. The mathematics syllabus in 1970 was in transition between the traditional syllabus and an alternative (new) syllabus.

Table 3: School Certificate grades 1970, 1979 : Percentages of boys and girls receiving each grade.*

	1970		1979	
	Boys	Girls	Boys	Girls
A	7	7	9	6
B	16	22	18	18

A sample of 1979 bursary grades was taken, looking at every seventh candidate. About sixty percent of the sample were males (fifty six percent of seventh formers were males in 1979). As would be predicted, boys sitting bursary mathematics outnumbered girls sitting bursary mathematics. Sixty-seven percent of pure mathematics candidates were males and eighty-three percent of applied mathematics candidates were males. While boys dominated the high bursary marks, the average bursary marks for boys and girls were not too dissimilar - 57% for males and 55% for females in pure mathematics and 58% for males and 54% for females in applied mathematics.

It seems then that girls are achieving as well, and participating in equal numbers to boys in mathematics at least up until the school certificate level. The question is why do girls not continue with mathematics in equal numbers to boys?

3 Cross-Cultural Studies

Husen (1967) in an analysis of data collected by the International Association for the Evaluation of Educational Achievement found a significant interaction between country and sex, suggesting that different factors operate across countries to provide different male/female results. Keeves (1973) found no uniformity across countries between sexes in the participation in education beyond a compulsory level. Differences across countries still favour men, but the differences vary from country to country. Keeves summarised the extent to which the achievement of boys exceeds that of girls as follows:

"The range of differences across countries is too great for a simple explanation to be advanced as to why such sex differences should have been observed. Furthermore, no combination of factors operating together comes readily to mind. Nevertheless, it is clear from this evidence that girls tend to be less well prepared to enter occupations and careers that require a prior knowledge of mathematics and science".

4 Spatial Visualisation and Problem Solving

Researchers have tried to identify the process or processes which occur and result in the under-representation of females taking higher levels of mathematics. Spatial visualisation is one such variable that has been considered. In some cases it has been proposed that spatial visualisation is an innate trait which favours males. However spatial visualisation may also be affected by environmental factors. Serbin (1979) found a link between visio-spatial ability in children and a preference for certain toys which had a masculine image. Fennema and Sherman (1977) considered practice and relevant experience to be factors in the differences between the sexes on spatial visualisation.

Tyler (1969) concludes that differences between the sexes in the area of spatial visualisation are not large when compared with differences within each sex group. Fennema and Sherman (1977) considered that females' very slightly lower skills on spatial

mathematical ability. Verbal ability, in which girls usually outperform boys, has also been correlated with mathematical ability. While spatial visualisation skills are important in learning mathematics, at best they could explain only a portion of the differences between the sexes in mathematics.

Wood (1977) found that girls in his study performed less well than boys on items that involved spatial visualisation and also items that involved quantification. The few items on which girls surpassed boys were those that did not demand problem solving behaviour. Resek (1980) also considers that girls do not perform as well on questions that they have not been programmed to answer. A Canadian National Assessment (1979) of over a hundred thousand students in grades four, eight and twelve produced similar results. Females were generally better than males on computational tasks, while males were better on higher order cognitive tasks.

Differences in problem solving behaviour may also be influenced by social factors. Hilton and Berglund (1976) for example found that boys had more practice and experience out of school with concepts relevant to mathematics. It is not unreasonable to suppose therefore that when faced with a novel mathematics situation boys would have more experiences to draw on. Carey (1957) considered sex differences in mathematics problem solving to be a function of sex differences in attitude. Men, Carey contends, tend to be more favourably disposed toward problem solving because they have been encouraged in this attitude.

5 Achievement

There is some evidence that sex related differences in mathematics learning may not be as large now as they have been in previous years. (Fennema and Sherman 1977, Keeves 1968, Keeves and Schrom 1977)

Fennema and Sherman (1977) considered also that many studies that reported large sex differences in achievement had not taken into account the level of mathematics being studied and were therefore comparing students with different opportunities to learn mathematics, girls being at a disadvantage. When Fennema and Sherman tested a group of older students of similar ability taking the same level of mathematics the differences between the sexes were not great.

Schildkamp-Kundiger (1980) argues however that there are limitations to this viewpoint. The National Assessment of Educational Progress in the United States in 1978 reported very little difference by gender in course taking. Among gifted students large sex differences were found on the scholastic aptitude mathematics text (Fox 1976). An explanation could not be given in terms of differential course taking. Some of the differences appeared as early as the seventh grade.

6 Attitudes

Generally girls are reported as having more favourable attitudes to school and school learning than boys at the primary level. Stright (1960) found that elementary school girls in the study liked arithmetic better than boys. Keeves (1972) considered the girls in his study to have more favourable attitudes to school and school

girls in science but not in mathematics. Hilton and Berglund (1976) in their study found no sex differences in mathematics achievement at grade five but thereafter boys pulled ahead and parallel differences emerged in boys perceiving mathematics as being interesting and likely to be helpful in earning a living.

a Attitudes and achievement

Research on the relationship between attitudes to and achievement in mathematics has not produced consistent findings. When significant correlations are found between attitude and achievement they generally range from .2 to .4, accounting for four to sixteen percent of the variance (Suydam 1975). Aiken (1970) states that "the relationship between attitudes and performance certainly is a consequence of a reciprocal influence in that attitudes affect achievement and achievement affects attitudes". The inconsistencies may arise to some extent from the fact that "attitudes are not well defined entities"¹.

Aiken and Dreger (1961) and Reese (1961) found in their studies that attitude scores were more highly correlated with both ability and achievement measures for females than for males. Fennema and Sherman (1978) also consider that sex role attitudes are more important for girls as learners of mathematics than boys.

b Mathematics as useful

A number of attitude factors have been proposed as differentiating between the sexes with regard to mathematics. The perception of the usefulness of mathematics is one such factor, with significantly more boys than girls perceiving mathematics as useful. (Fennema and Sherman 1977, Hilton and Berglund 1976). Responses to this attitude are good predictors of course taking in mathematics (Haven 1972, Fennema and Sherman 1977). Those who perceive mathematics as useful are not surprisingly more likely to take mathematics courses. At younger ages there are no sex differences on this variable, both sexes being equal in their perception of the usefulness of mathematics. Hilton and Berglund (1976) reported sex differences on this variable becoming apparent after grade five. Sex-related achievement differences appear only when there are sex differences in regarding mathematics as useful (Fennema and Sherman 1977, Hilton and Berglund 1976).

c Confidence in mathematics ability

Another attitude factor that has been identified is confidence in ability to do mathematics. Often girls underestimate their ability

¹ Schildkemp-Kundiger, E. Mathematics and Gender. Paper presented at the International Conference on Comparative Studies at Mathematics Curricula. January 1980, page 7.

to do mathematics. Fennema and Sherman (1977) found in their study that girls reported less confidence in their ability to do mathematics even before there were differences in performance. Fox (1977) found that women rated their ability high in social fields but low in mathematics.

d Socialisation/sex typing

Fennema and Sherman suggested that the stereotyping of mathematics as a male domain may be a mediating variable affecting a variety of related attitudes, such as confidence and/or the perception of the usefulness of mathematics. Newer studies suggest that the stereotyping of mathematics as a male domain is not as prevalent as it once was (Fennema and Sherman 1977, Schildkamp-Kundiger 1973), though it may still be a mediating variable.

It appears that girls attitudes to sex-role stereotyping become more flexible with age and as girls get older they increase their rejection of the idea of mathematics as a male domain (Dwyer 1974, Meyer 1980, Fennema and Sherman 1978), yet their behaviour in terms of mathematics course taking and career aspirations for the majority is still along tradition lines. Fennema and Sherman (1978) found that boys at high school in their study stereotyped mathematics as a male domain significantly more often than did girls. Schildkamp-Kundiger having reviewed recent studies considers that the evidence shows that male prejudice against female involvement in mathematics still exists or at least that females believe it to exist.

Socialisation processes in general and the expectations of significant others are two further areas to be considered. Some authors have proposed that achievement, especially in the mathematics field, is incompatible with the feminine role. Stein and Bailey (1973) consider that child rearing practices that are conducive to feminine sex typing are often antagonistic to achievement orientated behaviour. Studies have interpreted sex role socialisation as learning what is appropriate and what is inappropriate for one's sex. (Stein and Smithells 1969, Dwyer 1974). Mathematics, as indicated earlier, is viewed as an inappropriate area for women.

Some theorists have speculated on a "motive to avoid success" in women. This relates to the conflict between achievement and the feminine role that some researchers feel women experience. At first this appeared to provide a neat explanation of why women avoided certain areas such as mathematics. However Blackstone and Weinreich-Haste (1980) in their review suggest that "this phenomenon is neither so wide-spread or as simple as it first appeared".

Studies have shown that middle class daughters of working women have less stereotyped sex-role concepts than middle-class daughters of non-working women. (Miller 1975, Vogel, Broverman, Clarkson and Rosenkratz 1970). Meyer (1980) did not replicate this finding with a sample of working class women and their daughters. It has been suggested that maternal role satisfaction is more important than maternal employment in determining girls' sex role attitudes (Gold and Andres 1978).

Reinforcing sex roles are such items as school mathematics text books. A survey by the Research and Statistics Division of mathematics textbooks used in New Zealand schools found that women were both proportionately under-represented and tended to be confined to a narrow stereotyped range of occupations and activities. Gizycki (1976) in a review of Australian mathematics textbooks produced similar conclusions.

7 Women in mathematics-related fields

A number of studies have looked at women who have entered mathematics related fields to try and identify any variables which differentiate them from women in traditional fields. Lambert (1960) reported that female mathematics majors in his study were more feminine on the Mf scale of the Minnesota Multiphasic Personality Inventory (MMPI) than female non-mathematics majors. Stamp (1979) however found girls taking A-level mathematics to be less feminine on the California Personality Inventory (CPI) scale than girls taking A level French, but to be more reserved, stable, toughminded, radical and group dependent. Results depend very much on the definition of femininity.

Identification with the father, or masculine identification as measured by tests has been proposed as a necessary condition for achievement in mathematics by women. Fox (1977) however concludes that evidence for this position is not overwhelmingly impressive. Hawley (1971) found that women in her study preparing for traditional feminine careers believed that significant men in their lives divided attitudes and behaviours into male and female categories, whereas those women preparing for non-traditional careers did not think that significant men in their lives held such views.

8 Home environment

The home environment has been examined to investigate possible influencing factors. Parsons (1979) reported that fathers in the study of parents and children from grades five to eleven expressed more positive attitudes to mathematics and more confidence in their ability to do mathematics than mothers. These beliefs were specific to mathematics. Parsons considered that the role of these differences in the socialisation of childrens' mathematical concept was minimal. Parsons did find, however, that parents had sex differentiated perceptions of their children's mathematics aptitude, despite the similarity in boys and girls actual mathematics performance. While parents did not rate their daughters' mathematical ability as lower than their sons they thought that mathematics was harder for their daughters and that their daughters had to work harder to do well in mathematics. Previous work has found that girls think they have to work harder than boys to do well in mathematics. Fennema and Sherman (1978) reported that boys perceived their parents as more positive towards them as learners of mathematics than did girls. These differences began in middle school and became significant at high school. At younger ages there were no differences between boys and girls in their perceptions of their parents' attitudes towards them as learners of mathematics.

Keeves and Schrom (1977) collected data on a number of home variables which showed few differences between the sexes in child rearing and socialisation practices in the home. Parents did however report that boys were given greater freedom of exploration, had more emphasis placed on competition and were given more encouragement to discuss a wider range of topics. Parents expressed a higher level of aspiration for boys than for girls. Parsons found that parents in the study viewed mathematics as more important for boys. Evidence suggests that males and females are exposed to different attitudes and treatments at the home level. The future plans and current expectations of children in Parson's study were related to the individual child's mathematics self concept and to their perception of their parents' belief about the child's mathematics aptitude and potential.

9 School environment

The school environment itself has received consideration. In a similar finding to that of the home environment, Fennema and Sherman (1978) reported that boys perceived teachers as more positive towards them as learners of mathematics than did girls at the tenth grade level. Once again those differences were not apparent at younger ages.

Parsons (1979) looked at individual teacher effects in seventh and ninth grades. Classes were divided into those whose teachers were found to have high sex differences in expectations regarding mathematics and those whose teachers had low sex differences in expectations. Teachers of classes with high sex differences in expectations were more critical of work form and conduct, gave more praise for work from boys, were more likely to use a public teaching style, less likely to use dyadic interactions and were more likely to rely on student volunteers to answer rather than directing class participation by calling on specific children. Girls for whom the teacher had high expectations were treated differently in each of the classroom types. In the classes with low sex differences in expectations bright girls interacted more, answered more questions and received less criticism than those in classes with high sex differences in expectancies. Brophy and Good (1970) reported that in high school mathematics classes high achieving boys received significantly more attention from both male and female teachers than did high achieving girls. In their study Leinhardt, Seewald and Engel (1979) found that teachers made most academic contacts with girls in reading and boys in mathematics. Gregory (1977) concluded that mathematics teachers in his study were less concerned about providing remedial help to females than they were to males.

In a study by Fennema (1977) teachers rewarded computational behaviour from girls and higher level cognitive skills, such as problem solving, from boys. Differences have also been recorded in the way that teachers criticise pupils. Dweck considers that girls learn helplessness from the type of feedback that they receive from the teacher. The type of criticism that girls receive is interpreted as bearing on their own ability whereas the

similar pattern right through the education system. It appeared in the study by Fennema (1977) that teachers were inaccurate in their perceptions of girls feelings about mathematics. Fennema considered that this situation may have been caused at least in part by the teachers stereotyping mathematics as a male domain. "Whatever the explanation," Fennema concludes, "it is clear that teachers do perceive males and females differently as learners of mathematics".

It has been suggested that boys and girls have different cognitive styles and that certain teaching styles may appeal more to boys than to girls. Fennema proposes a theory regarding cognitive styles and sex related differences in mathematics. She points out that many mathematical problems can be solved by the use of symbols and/or by the use of figures or drawings. By choosing one strategy over another a teacher may strongly support the learning process of pupils using the equivalent styles. If girls, for whatever reason, prefer the verbal dimension and teaching procedures using concrete and pictorial representations are used in the early school years to teach mathematics this may lead at least to a partial explanation of sex related achievement differences. Teacher styles may be an interesting area for further investigation.

9 Type of School

Comparisons have been made between girls mathematical achievements in single sex and co-educational schools. Husen (1967) in an international evaluation reported that sex differences in total mathematics score were generally less in countries with more coeducational schools but this varied across countries and across populations. The reverse relationship was recorded for interest in mathematics. British surveys have revealed two major findings with regards to this issue. While studies have reported boys performance in coeducational schools as either improved over single sex schools (Dale 1974) or at least comparable with single sex schools (Blackstone and Weinreich-Haste 1980), girls in mixed schools appear to do less well than girls in single sex schools (Dale 1974, Blackstone and Weinreich-Haste 1980). A study in Sneathfield schools showed girls doing relatively poorly at mathematics after age eleven, but that this situation only existed in mixed schools. The second reported finding is that mixed schools tend to polarise subject interest so that boys cluster in mathematics and science subjects and girls in the arts subjects (Department of Education and Science, United Kingdom 1975, Blackstone and Weinreich-Haste 1980).

In New Zealand the pattern seems to be different with girls in coeducational schools being slightly more likely than those in single sex schools to take mathematics in the sixth and seventh forms.

Table 4 : Percentages taking full mathematics courses by type of school New Zealand 1980

	Form 5 1st year	Form 5 other	Form 6	Form 7
Single sex boys	96	92	89	78
Coed boys	88	79	85	75
Single sex girls	84	50	62	55
Coed girls	84	69	67	58

In an experiment at a coeducational secondary school near Manchester, a girls only mathematics group was established. This was because teachers found boys pulling ahead of girls in mathematics achievement. The teachers felt that girls tended to take a quiet back seat in mixed sex mathematics lessons fearing ridicule from the boys if they gave the wrong answer. Girls in the "all girls" class achieved markedly better results than girls in the normal "mixed" class. It should be noted however that the girls in the all girls class were receiving special attention and that this may have contributed to the results.

There is no information available on examination results for different types of schools in New Zealand.

10 Careers

Wise (1979) found that when the level of the students' ability was controlled for the most significant predictor of mathematics course participation was the level of interest the student expressed in a mathematics related career. Fogelman (1979) in his study of the career aspirations of twelve thousand British sixteen year olds found "the most striking and consistent pattern to emerge from the data to be that of sex differences". As with Wise student career aspirations were very much divided along traditional lines with few female students aspiring to mathematics-related careers.

Information concerning the probable destination of New Zealand school-leavers gives only broad categories of intended occupation. For those planning to go to university however it is likely that women will be under-represented in science and mathematics courses. (Tables 2a and 2b). Boys predominate among those indicating that they are likely to enter an apprenticeship on leaving high school, while girls outnumber boys in the group intending to attend teachers college.

A sample of occupations from the 1976 census also shows women to be outnumbered in mathematics related occupations.

Table 6: Sample of Occupations from the 1976 Census

	Males	Females
Physical scientists and technicians	3,133	1,314
Architects, engineers, technicians	22,639	1,062
Aircraft and ships officers	2,821	4
Statisticians, mathematicians, systems analysts and technicians	1,290	248
Accountants	7,170	264
Teachers	18,446	25,834
Stenographers, typist, punch machine operators	526	33,866
Total actively engaged in the workforce	865,098	407,235

11 Summary

Studies vary in their reports of exactly when sex differences in mathematics achievement emerge, but generally it is reported that there are few if any sex differences in mathematics performance at the primary level but that at high school boys pull ahead. When mathematics becomes an optional school subject girls are less likely than boys to opt for mathematics. Even when participation and achievement are almost equal in middle high school for boys and girls, as is the case with recent New Zealand school certificate exams, girls are still less likely than boys to continue with mathematics.

Many possibilities have been investigated to try to explain this situation. Differences in what may be termed cognitive styles, mainly spatial visualisation and problem solving to date, are among those variables which have been proposed. Some researchers have argued that the cause of such differences is innate, that boys genetically are more predisposed to mathematics than girls. However, environmental explanations have also been proposed. Boys and girls are reported as being exposed to different experiences in both the home and school. Among the variables investigated have been the types of toys that boys and girls are given, parental aspirations, and teaching styles. In a number of studies boys have been found to receive treatment which is considered to be more favourable to the development of mathematical skills than the treatment that girls received.

Studies have also focussed on socialisation processes and sex roles. Mathematics, say some authors, is considered as an area more appropriate for men. As a result women are less likely to strive to achieve in the mathematics field. Attitude studies have found girls to report less confidence in their ability to do mathematics more often than boys do, even in some cases where their actual performance is equal to that of boys. Another finding has been that girls perceive mathematics as useful less frequently than boys do. It has been suggested that sex-role socialisation is primarily concerned with learning what is inappropriate for one's sex. Parents as sex role models, parental expectations and teacher treatment of students have been studied to investigate influences

Such a wide variety of possible influences has led Aiken (1975) to suggest the need for both longitudinal and short term studies to determine the effects and interactions of many variables. Useful investigations could look further into the relationship between the development of attitudes towards mathematics and participation and achievement in mathematics. The classroom itself could be a base for research, looking at teaching styles, teacher perceptions of boys and girls as learners of mathematics and classroom processes themselves.

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